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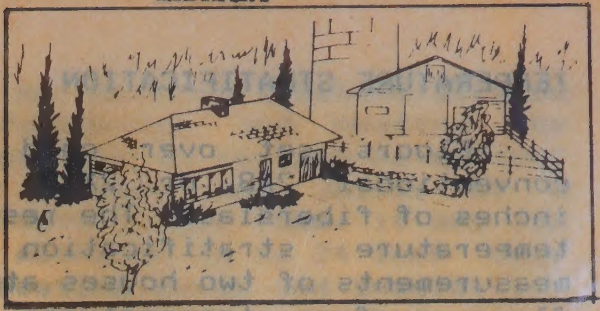

Building in Alaska

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EFFICIENT ENERGY DESIGN CONSIDERATIONS FOR ARCTIC RESIDENCES

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ABSTRACT

The effect of different types of foundations and floor framing systems are discussed as they relate to efficient energy conservation design considerations for arctic residences. Although a basement cannot be used in certain permafrost susceptible soils, it is estimated that heating costs are 46 percent less than than an equivalent ranch style house set on an open post and beam foundations or masonry crawl space foundation. Further, a basement house resulted in an estimated 43 percent reduction in building costs for comparable liveable floor space. Where an open crawl space foundation must be used in permafrost susceptible soils, conventional 8 or 10 inch joist framing systems result in cold floor surface temperatures and wide temperature differentials between the ceiling and floor. Deep, long-span lumber-plywood joists used as a warm plenum floor can result in greater comfort with an estimated 23 percent reduction in heating costs and less than one percent increase in total building costs as compared to conventional floor joists.

INTRODUCTION

Residences in the interior of Alaska sited on permafrost susceptible soils are built over foundations with an open crawl space to minimize transfer of heat from the floor into the frozen ground. Melting of the permafrost can cause uneven settlement of the foundation and racking of the framing system (1). Conventional methods of framing the floor with three or more rows of simple (short-span) beams and two or more simple span floor joists does not provide sufficient rigidity to the house. Tying the ends of floor joists with a single header also limits the strength of the wall. All of these factors in combination with heaving and settling of a single or group of piers may cause uneven settlement of the structure with the sticking of doors and windows. Excessive movement of the foundation can also open up a crack between wall plate and the floor, and other areas, allowing excessive air infilration and sifting of silt or snow into the house.

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TEMPERATURE STRATIFICATION

Floors set over cold crawl spaces are usually framed with conventional 2X8 or 2X10 joists and insulated with either 6 or 9 1/2 inches of fiberglass. The resultant cold floor surfaces cause severe temperature stratification from the floor to the ceiling. Field measurements of two houses at Point Barrow, Alaska in 1971 revealed floor surface temperatures of 58 Deg-F and 68 Deg-F respectively at thermostat settings of 73 Deg-F and 83 Deg-F, (2). Air temperatures of 63 Deg-F and 73 Deg-F respectively were observed an inch or two above the floor. Just below the ceiling, air temperatures of 83 Deg-F and 93 Deg-F respectively, were observed. At the peak of the heating cycle an air temperature of 105 Deg-F was observed near the ceiling. In colder bedrooms, with improper heat distribution, floor surface temperatures of as low as 32 Deg-F was measured at an outdoor temperature of minus 25 Deg-F. The latter resulted in the formation of condensation on the lower portion of the wall and the perimeter of the floor. Similar conditions have been observed in mobile homes, modular homes, stick-built houses and commercial buildings erected on open or plywood skirted crawl spaces. The improper sizing and balancing of the heating system may also contribute to uneven heating.

HEATING DEGREE DAYS

Thermostat settings of 75 Deg-F to 85 Deg-F are common in the interior of Alaska in an attempt to compensate for the cold air temperatures near the floor. As would be expected, this results in higher heating costs. Heating engineers and contractors from the lower 48 still estimate annual heating requirments based on heating degree day tables computed on a 65 Deg-F (average) temperature (3). These degree day values were originally based on average daily interior temperature of 65 Deg-F, which was satisfactory with the furnace installed in the basement. However, it has become evident that Alaskan residents living in houses set on a cold crawl space must set thermostats at a higher level to maintain a warmer floor air temperature.

Annual heating degree days are normally obtained by subtracting the annual mean outdoor temperature from the 65 Deg-F indoor base (average) temperature and multiplying it by 365 days. The annual heating degree days for indoor (base) temperatures of 65, 70, 75, 80 and 85 deg- F, and an outdoor annual mean temperature of 25.6 Deg-F (Fairbanks) and 50 Deg-F are listed in Table 1.

The base (average) temperature should be varied according to the comfort level requirements of each household. As a result, the variance in degree days (base temperature) can result in as much as 50 percent difference in heating requirements from one house to another in the interior of Alaska. Surprising as it may seem, the lower heating degree values of warmer climates can result in as much as a 133 percent variance in heating requirements.

WARM FLOOR CAVITY

Research conducted by the United States Department of Agriculture in 1965 indicated that the comfort level and heating requirments of a house set on an open crawl space could be improved substantially by installing insulated skirting around the foundation and heating the crawl space (4). However, this is not feasible in certain permafrost susceptible soils. Unfortunately, the space between the joists of a conventional floor framing system leaves very little room, if any for insulation and the circulation of warm air. Although 16 to 24 inch deep trussed floor joists would accomodate both heating ducts and insulation, their cost may be prohibitive for low cost housing in bush areas of Alaska. Prefabricated trusses require a certain amount of sophisticated field skill to build during the short building season of Alaska. Hence, the 16 to 20 inch deep channel lumber plywood joists constructed of either 2X4 or 2X6 flanges and a single 1/2 or 5/8 inch plywood web, spaced at 24 or 48 inch centers is suggested (5). Prefabricated plywood-lumber I-beam joists are being used in multi-family residential construction in Fairbanks.

HEATING AND BUILDING COST ANALYSIS

Detailed bills of material and cost estimates were prepared for a 24-0 X 32-0 story house to determine the effect of different types of floor framing and foundations on total heating and building costs based on 1975 Fairbanks labor and material prices. The electronic computer program that was developed in 1973 (6, 7) facilitated the systematic computation and tabulation of the square foot costs for the various structural components needed for this study. The heating and building costs were based on the comparable exposed floor, window, door, wall and roof areas, including foundation (basement) walls and floor surfaces below grade. The various exposed areas and infiltration (CFM), thermal coefficients and simulated air temperatures adjacent to exposed surfaces were included as input.

The structural heat losses (BTU/Hr/Deg-F) were obtained by multiplying the exposed surface area and infiltration (CFM) by respective thermal coefficients. Rather than using heating degree days based on 65 Deg-F average temperature, the hourly heat loss (BTU/Hr) of each exposed area was obtained by multiplying the structural heat loss (BTU/Hr/Deg-F) by the temperature differential of adjacent interior air temperatures and annual mean exterior temperature. A ten year annual mean temperature of 25.6 Deg-F was selected for Fairbanks. Fuel oil costs for Fairbanks reached $0.529 per gallon during the 1975 heating season.

The heating and building costs for various types of floor framing and foundations selected for this study are summarized in Table 2. The insulation thicknesses of exposed surfaces are listed in the table. The awning windows were double glazed and accounted for 107 square feet of the wall area. The two doors were provided with storm doors. The conventional floor was framed with 2X10 joists at 24 inch centers. The heated plenum floor was framed with 20-inch deep lumber-plywood joists constructed of 2X4 flanges laid vertically and 1/2 inch plywood webs. Joists were spaced at 24 inch centers. A counter-flow furnace was selected with hot air ducts extending to each room and using the plenum as a return.

Although the warm plenum (lumber-plywood joists) of House 15 costs

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$250.00 more than the conventional floor of House 4, the annual heating costs were $160.00 to $197.00 lower, depending on the temperature comfort level. The net annual heating and mortgage payments favored the warm plenum floor over the conventional floor by $76.00 to $135.00 depending on the temperature level selected.

It is possible to maintain a warm floor by setting the house over a heated crawl space or basement. Using the plenum floor, House 15B as a base, and comparable floor air temperatures, the uninsuslated masonry foundation , House 21, would cost an additional $354.00 to heat and $408.00 to build, for a net annual increase in heating and mortgage payments of $400.00. Insulating the crawl space, House 23A, would still result in $138.00 higher heating costs and $1,242.00 higher building costs, with a net annual increase in heating and mortgage payments of $264.00.

Although the uninsulated masonry basement, House 32, will increase the comfort level of the first floor, it will also increase the annual heating costs by $635.00 and total building costs by $6,555.00 as compared to the warm plenum foundation, House 15B. The net annual heating and mortgage payments would be increased by $1,297.00. Insulating the basement will improve the liveability of House 33 and decrease the annual heating costs by $372.00 and increase total building costs by $1874.00, with a net decrease in annual heating and mortgage payments of $183.00. A net increase in annual heating and mortgage payments of $1114.00 would occur over the warm plenum foundation, House 15B.

The treated wood foundation has been approved by FHA-HUD for house construction, and seems to be an economical technique for improving the thermal efficiency of a house. The uninsulated treated wood foundation, House 27, would increase annual heating costs by $125.00 and decrease total building costs by $809.00 as compared to House 21, for a net increase in annual heating and mortgage payments of $39.00. Insulating the treated wood foundation would decrease heating costs $360.00 and increase total building costs by $932.00, for a net decrease in annual heating and mortgage paymnents of $266.00. The insulated treated wood foundation would result in a net increase in annual heating and mortgage payments of $127.00 over the warm plenum foundation, House 15B.

The insulated treated wood basement, House 36B, would result in one dollar decrease in heating costs and a $3873.00 decrease in building costs compared to the insulated masonry basement, House 33. The insulated treated wood basement would result in an annual net inrease in heating and mortgage payments of $732.00 as compared to the warm plenum foundation, House 15B.

If additional living space is needed, a house with an insulated daylight basement will cost less to build and heat. Based on a comparable area of 1,536 square feet of liveable space, a 24-0 X 64-0, one story ranch style house, 15B with a warm plenum would cost $67,458.00 for a square foot cost of $43.92. A 24-0 X 32-0 2 story house with insulated basement, House 33, would cost $42,158.00, for a square foot cost of $27.45. This would amount to a total savings in building costs of $25,300.00, which amortized over the life of the mortgage would

TABLE 2. SUMMARY OF HEATING AND BUILDING COSTS.

HOUSE NO	FOUNDATION TYPE	INSULATION FL-FD-WL-RF INCHES	TEMPERATURE FL-WL-RF-AV DEG-F	HEAT LOSS BTUHF	FUEL COST ($)	BUILDING COST ($)	MORTGAGE YR-PMTS ($)	ANNUAL SAVING ($)
4A	OPEN CRAWL	6-3-6	65-75-85-75.1	289.	721.	33,479.	3,378.	+ 59.
4B	OPEN CRAWL	6-3-6	70-85-95-85.0	289.	834.	33,479.	3,378.	+ 172.
15A	WARM PLENUM	6-3-6	65-65-65-65.0	289.	561.	33,729	3.403	- 76.
15B	WARM PLENUM	6-3-6	70-70-70-70.0	289.	637.	33,729.	3,403.	BASE
21	MAS CRAWL	0-3-6	65-70-75-68.2	470.	991.	34,137.	3,449.	+ 400.
23A	MAS CRAWL	1-1-3-6	65-70-75-69.2	359.	775.	34,971.	3,592.	+ 264
27	TRT WD CRAWL	0-0-3-6	65-70-75-67.9	533.	1,116.	33,328.	3,363.	+ 439.
28A	TRT WD CRAWL	1-1-3-6	70-70-75-69.5	348.	756.	34,260.	3,457.	+ 173.
32	MAS BAS	0-0-3-6	65-70-75-67.5	614.	1,272.	40,284.	4,065	+1,297.
33	MAS BAS	1-1-3-6	70-70-75-70.3	407.	900.	42,158.	4,254.	+1,114.
36A	TRT WD BAS	0-0-3-6	65-70-75-67.5	614.	1,272.	37,441.	3,778.	+1,010.
36B	TRT WD BAS	1-3-3-6	70-70-75-70.3	406.	899.	38,376	3,873.	+ 732.

NOTES:
1.House, 1-story, 24-0x32-0
2.1975 Fair banks labor and material prices
3.Fuel cost $0.529 per gallon
4.Mortgage: 33 years at 9.5 percent interest
5.Windows: 107 SF 1st floor and 41 SF basement
6.Fiberglass insulation, except 1" is foam platic.
7.Annual mean temperature of 25.6 Deg-F
8.Ground design temperature of 4 Deg-F.

result in an annual savings of $2,552.00. At the same time, the basement house would result in an annual savings in heating of $$374.00. A net annual savings of $2,926.00 could be anticipated.

CONCLUSION

If home owners and builders are really concerned about energy conservation, the total energy required to process, package, transport and erect materials to build a house should be considered, as well as the energy required to provide heat and electricity. This study indicates a more energy efficient house can be built at lower costs by utilizing a daylite basement with no sacrifice in living space. Insulating the various types of foundations selected for the study resulted in a net savings in annual heating and mortgage payments. Although not included in this paper, previous studies by the author indicate that 1-1/2 and 2 story houses can be built for lower costs than 1 story ranch style houses.

TABLE 1. HEATING DEGREE DAY COMPARISONS.

TEMPERATURE BASE AVERAGE DEG-F	ANNUAL MEAN TEMPERATURE			
	25.6 DEG-F		50.0 DEG-F	
	DEGREE DAYS	HEATING INDEX	DEGREE DAYS	HEATING INDEX
65.	14,381.	1.00	5,475.	0.38
70.	16,206.	1.13	7,300.	0.51
75.	18,031.	1.25	9,125.	0.64
80.	19,856.	1.38	10,950.	0.76
85.	21,681.	1.51	12,775.	0.89

REFERENCES

1. Carlson, A.R., 1973; Permafrost - A Problem Of Building In Alaska, Cooperative Extension Service, Pub. P-754, University Of Alaska.

2. Carlson, A.R., 1973; Design Of Floors For Arctic Shelters, Cooperative Extension Service Pub. HSC-33, University Of Alaska.

3. ASHRAE, 1976: Handbook Of Fundementals.

4. Newman J.O., 1967; Heating Systems For Low Income Families, presented at the Economy Housing Seminar, University of Nebraska, Nov 13-15, 1967.

5. Carlson, A.R., 1976; Plywood Lumber Floor Joists Can Reduce Housing Costs, American Society Of Agricultural Engineering Technical Paper 76-403.

6. Carlson, A.R., 1973; The Effect Of Insulation On Heating And Building Costs, Cooperative Extension Service Pub. PR-358, University of Alaska

7. Carlson, A.R., 1974; An Electronic Computer Program For Calculating And Tabulating Building Costs, Cooperative Extension Service Pub. RP-953, University Of Alaska.

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